MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2018/2019

ETN3046 – ANALOG AND DIGITAL COMMUNICATIONS

(CE, EE, LE, NE & OPE)

13 OCTOBER 2018
9:00 AM – 11:00 AM
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 8 pages (including this cover page) with 4 Questions only and an appendix.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided.

Question 1

(a)

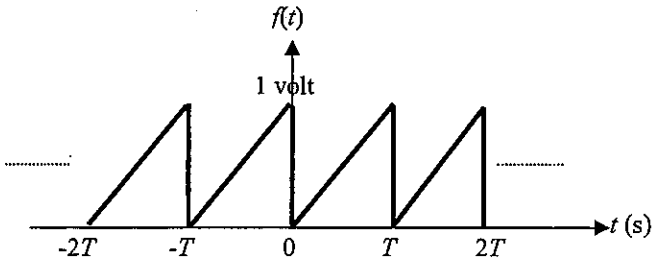

Fig. Q1.1 A periodic signal

Fig. Q1.1 shows a periodic amplitude waveform that can be expressed in the form of a trigonometric Fourier series as follows:

$$f(t) = A_0 + \sum_{n=1}^{\infty} A_n \cos\left(\frac{2\pi nt}{T}\right) + \sum_{n=1}^{\infty} B_n \sin\left(\frac{2\pi nt}{T}\right)$$

where

$$A_0 = \frac{1}{T}\int_T f(t)\ dt,$$

$$A_n = \frac{2}{T}\int_T f(t)\cos\left(\frac{2\pi nt}{T}\right) dt,$$

$$B_n = \frac{2}{T}\int_T f(t)\sin\left(\frac{2\pi nt}{T}\right) dt,$$

T is the period of the waveform.

(i) Suppose $T = 1$ s. Find A_0 and B_n, where $n = 1, 2, 3, 4$. [10 marks]

(ii) Express $f(t)$ by expanding the summation series. Take $A_n = 0$. [2 marks]

(b) The Fourier transform of $x(t)$ is given by $X(f) = \dfrac{1}{1 + j2\pi f}$. Find $Y(f)$, the Fourier transform of $y(t)$, for the followings:

(i) $y(t) = x(t-1)$ [3 marks]

(ii) $y(t) = e^{-jt}x(t)$ [4 marks]

(iii) $y(t) = e^{-jt}x(t-1)$ [6 marks]

Continued ...

Question 2

(a) The demodulation of double sideband suppressed carrier (DSB-SC) signal with carrier frequency f_c is shown in Fig. Q2.1. The message signal $m(t)$ is bandlimited to W as shown in Fig. Q2.2. $M(f)$ denotes the amplitude spectrum of $m(t)$. Assume that the DSB-SC signal is given by $s(t) = A_c \cos(2\pi f_c t)\, m(t)$.

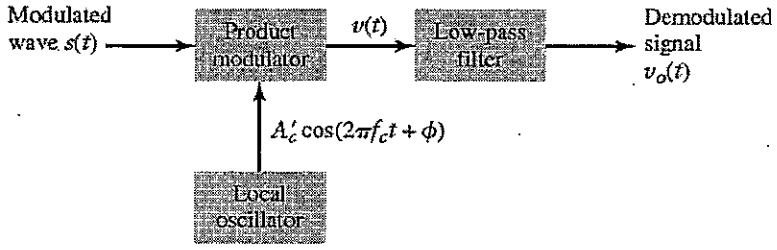

Fig. Q2.1 Coherent detection of DSB-SC signal

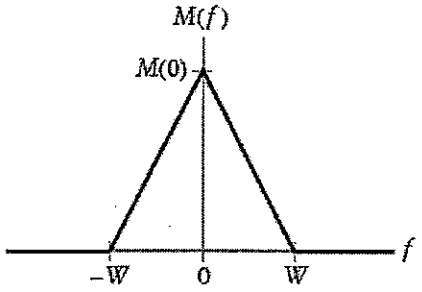

Fig. Q2.2 Amplitude spectrum of $m(t)$

(i) Determine $S(f)$, the amplitude spectrum of $s(t)$. Sketch $S(f)$. [4 marks]

(ii) Determine $V(f)$, the amplitude spectrum of $v(t)$. Sketch $V(f)$. [4 marks]

Useful trigonometric identity: $\cos A \cos B = \frac{1}{2}\left[\cos(A+B) + \cos(A-B)\right]$

(iii) Determine $V_0(f)$, the amplitude spectrum of $v_0(t)$. Sketch $V_0(f)$. [4 marks]

(b) A sinusoidal wave $m(t) = A_m \cos(2\pi f_m t)$, with amplitude A_m and frequency f_m, frequency-modulates a sinusoidal carrier of the amplitude A_c and frequency of f_c. It results in a frequency modulated (FM) wave that is expressed as follows:

$$s(t) = A_c \cos\left[2\pi f_c t + \beta \sin(2\pi f_m t)\right]$$

It is given that

$$A_c = 5\text{ V}, f_c = 1\text{ MHz}, f_m = 10\text{ kHz}$$
$$\text{Modulation index, } \beta = 2$$

The FM wave is supplied to a load of 1 Ω.

(i) Calculate the average power of the FM signal. [2 marks]

Continued ...

Question 2 (continued)

(b) (ii) What is the amount of transmission power that falls in the sidebands?

[3 marks]

(iii) The FM signal is passed through an ideal bandpass filter, which has a centre frequency of 1 MHz, a bandwidth of 40 kHz, and a gain of unity. Determine the average power measured at the output of the filter.

[8 marks]

Table Q2.1: Table of the Bessel Function of the First Kind

	$J_n(\beta)$							
n	$\beta = 0.2$	$\beta = 0.3$	$\beta = 0.5$	$\beta = 0.7$	$\beta = 1.0$	$\beta = 2.0$	$\beta = 3.0$	$\beta = 5.0$
0	0.990	0.978	0.938	0.881	0.765	0.224	-0.260	-0.178
1	0.100	0.148	0.242	0.329	0.440	0.577	0.339	-0.328
2		0.011	0.031	0.059	0.115	0.353	0.486	0.047
3					0.020	0.129	0.309	0.365
4						0.034	0.132	0.391
5							0.043	0.261
6							0.011	0.131
7								0.053
8								0.018

Question 3

(a) Fig. Q3.1 shows the block diagram of a digital communication system.

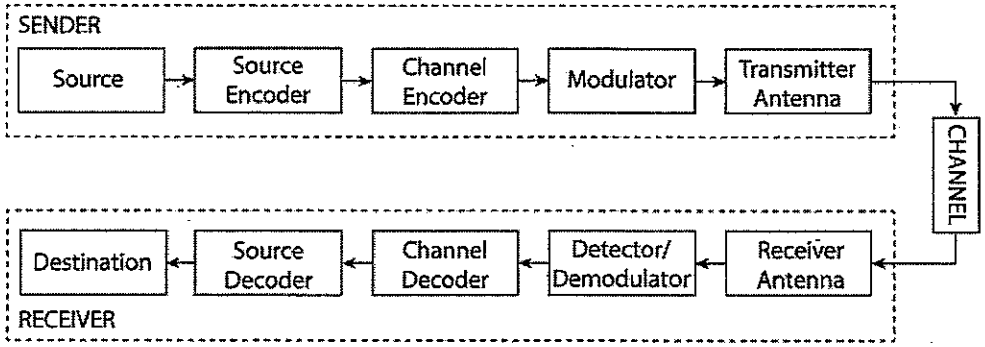

Fig. Q3.1

Briefly describe the functionality of the following components:

(i) Source encoder [2 marks]

(ii) Channel encoder [2 marks]

Continued ...

Question 3 (continued)

(b) (i) Define the Nyquist sampling theorem. [2 marks]

(ii) Fig. Q3.2 shows the spectrum of a bandlimited analogue signal. Illustrate the spectrum of a sampled version of this signal if instantaneous sampling is performed at a rate higher than the Nyquist rate. [4 marks]

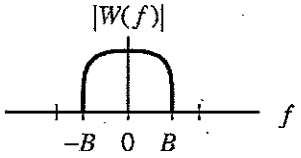

Fig. Q3.2

(c) An analogue signal is sampled, quantised, and encoded into a binary pulse code modulation (PCM) signal. Each quantised sample is encoded into a codeword, which is then line coded into six information pulses and a synchronising pulse. The line code pulses can take on two possible levels, and are transmitted over a channel of bandwidth 10.5 kHz using Nyquist filtering with 50% roll-off.

(i) Determine the *symbol rate* of the line code pulses. [2 marks]

(ii) Calculate the *information bit rate* of the PCM signal. [2 marks]

(iii) It is desirable to trade the number of quantisation levels for source bandwidth. If the number of quantisation levels is reduced by a factor of 4, determine the new source bandwidth. Assume Nyquist sampling rate is used. [4 marks]

(d) Define *coherence bandwidth* of a communication channel. With the aid of appropriate time and frequency-domian diagrams, briefly describe how intersymbol interference arises when transmitting a very high data rate signal over a channel with a narrow coherence bandwidth. [7 marks]

Continued ...

Question 4

(a) Fig. Q4.1 shows the constellation diagram of some noisy demodulated symbols using a specific digital modulation scheme.

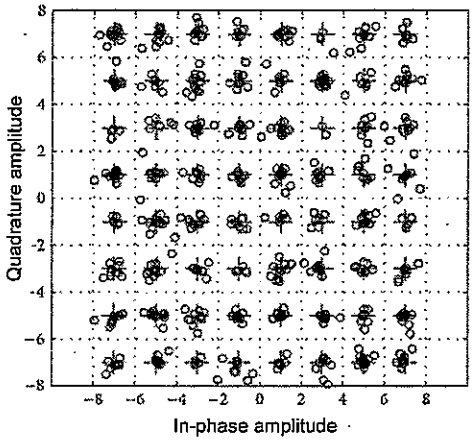

Fig. Q4.1

(i) Name this type of modulation scheme. [1 mark]

(ii) Determine the number of bits carried by each received symbol. [1 mark]

(iii) Why the received symbols fluctuate randomly around the transmitted symbols? [2 marks]

(b) A discrete memoryless source generates five messages $\{s_0, s_1, s_2, s_3, s_4\}$ with respective probabilities of occurrence $\{0.55, p_1, 0.15, 0.1, 0.05\}$.

(i) Determine p_1, i.e., the probability of occurrence for symbol s_1. [1 mark]

(ii) Obtain the Huffman code for these messages by moving a combined symbol as high as possible. [6 marks]

(iii) Calculate the average codeword length of the Huffman code. [1 mark]

(c) Briefly describe the two major approaches of error control for digital communication systems. [4 marks]

(d) Consider a Hamming (7,4) code with the following parity-check matrix **H**.

$$\mathbf{H} = \begin{bmatrix} 1 & 1 & 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 & 1 \end{bmatrix}$$

(i) Obtain its generator matrix **G**. [2 marks]

(ii) Is this Hamming code a systematic code? Justify your answer. [2 marks]

(iii) Given that codeword {0 0 0 1 1 1 0} is received, calculated the syndrome and investigate if an error has occurred. If it has, perform error correction using syndrome decoding. [5 marks]

End of Questions

APPENDIX

Table of Fourier Transform Pairs

$x(t)$	$X(f)$
$\delta(t)$	1
$\delta(t-t_o)$	$e^{-j2\pi f t_o}$
1	$\delta(f)$
$e^{j2\pi f_o t}$	$\delta(f-f_o)$
$u(t)$	$\frac{1}{2}\delta(f)+\frac{1}{j2\pi f}$
$e^{-at}u(t)$	$\frac{1}{a+j2\pi f}$, for $a>0$
$e^{at}u(-t)$	$\frac{1}{a-j2\pi f}$, for $a>0$
$e^{-a\lvert t\rvert}$	$\frac{2a}{a^2+(2\pi f)^2}$, for $a>0$
$rect\left(\frac{t}{T}\right)$	$T\text{sinc}(fT)$
$\text{sinc}(2Wt)$	$\frac{1}{2W}rect\left(\frac{f}{2W}\right)$
$\Delta\left(\frac{t}{T}\right)$	$\frac{T}{2}\text{sinc}^2\left(\frac{fT}{2}\right)$
$W\text{sinc}^2(Wt)$	$\Delta\left(\frac{f}{2W}\right)$
$e^{-\pi t^2}$	$e^{-\pi f^2}$
$\cos(2\pi f_o t)$	$\frac{1}{2}\delta(f-f_o)+\frac{1}{2}\delta(f+f_o)$
$\sin(2\pi f_o t)$	$\frac{1}{2j}[\delta(f-f_o)-\delta(f+f_o)]$
$\text{sgn}(t)=\begin{cases}1 & t>0\\ -1 & t<0\end{cases}$	$\frac{1}{j\pi f}$
$\frac{1}{\pi t}$	$-j\,\text{sgn}(f)$

Table of Fourier Transform Properties

Let $x(t) \Leftrightarrow X(f)$, $x_1(t) \Leftrightarrow X_1(f)$ and $x_2(t) \Leftrightarrow X_2(f)$; and a, b, t_o and f_o scalar quantities.	
Linearity	$ax_1(t)+bx_2(t) \Leftrightarrow aX_1(f)+bX_2(f)$
Duality	$X(t) \Leftrightarrow x(-f)$
Scaling ($a \neq 0$)	$x(at) \Leftrightarrow \frac{1}{\lvert a \rvert} X\left(\frac{f}{a}\right)$
Time Shifting	$x(t-t_0) \Leftrightarrow X(f)e^{-j2\pi f t_0}$
Frequency Shifting	$x(t)e^{j2\pi f_0 t} \Leftrightarrow X(f-f_0)$
Modulation	$x(t)\cos(2\pi f_0 t) \Leftrightarrow \frac{1}{2}X(f-f_0)+\frac{1}{2}X(f+f_0)$
Time Convolution	$x_1(t)*x_2(t) \Leftrightarrow X_1(f)X_2(f)$
Frequency Convolution	$x_1(t)x_2(t) \Leftrightarrow X_1(f)*X_2(f)$
Time Differentiation	$\frac{d^n}{dt^n}x(t) \Leftrightarrow (j2\pi f)^n X(f)$
Frequency Differentiation	$(-jt)^n x(t) \Leftrightarrow \frac{d^n}{df^n}X(f)$
Time Integration	$\int_{-\infty}^{t} x(\tau)d\tau \Leftrightarrow \frac{X(f)}{j2\pi f}+\frac{1}{2}X(0)\delta(f)$
Frequency Integration	$x(t)u(t) \Leftrightarrow \int_{-\infty}^{f} X(\tilde{f})d\tilde{f}$